Robust Positioning – Provision of Safe Navigation at Sea

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Agenda

- Motivation
- Our Work
- Case Study
- Summary and Outlook

source: www.waterways-forward.eu

Motivation: Importance of Nautical Systems

- Maritime transport is the **backbone** of international trade and the global economy:
  - ~80% global trade by volume is made by sea
  - Around 400 Mio. passengers move through European ports each year

Nautical Transport Systems are **essential** for the economic development, competitiveness and prosperity

Transport volume increases year by year… and results into

- increasing traffic densities
- larger vessels

Source: www.hamburg.com

Motivation: Problem Statement

Grounding on reef of the *Rena* container ship in 2011

There is a large amount of marine accidents !

✗ Enormous material losses, severe ecological damage

Crashed against the Danish Great Bridge of the *Karen Danielsen* ship in 2005

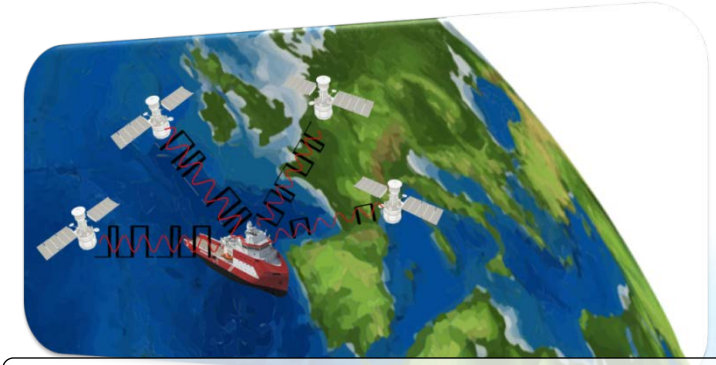
Navigational accidents are induced by:

- **invalid or inaccurate nautical information**
- **misinterpretation of navigation data**
- **incomplete situation awareness**
- **…**

Our Work

Provision of safe navigational data to minimize the risks of accidents, to avoid the loss of life and goods and to protect the environment.

- **What is our solution?** ⇒ Sensor fusion to estimate accurate and reliable position, velocity, orientation of the vessel

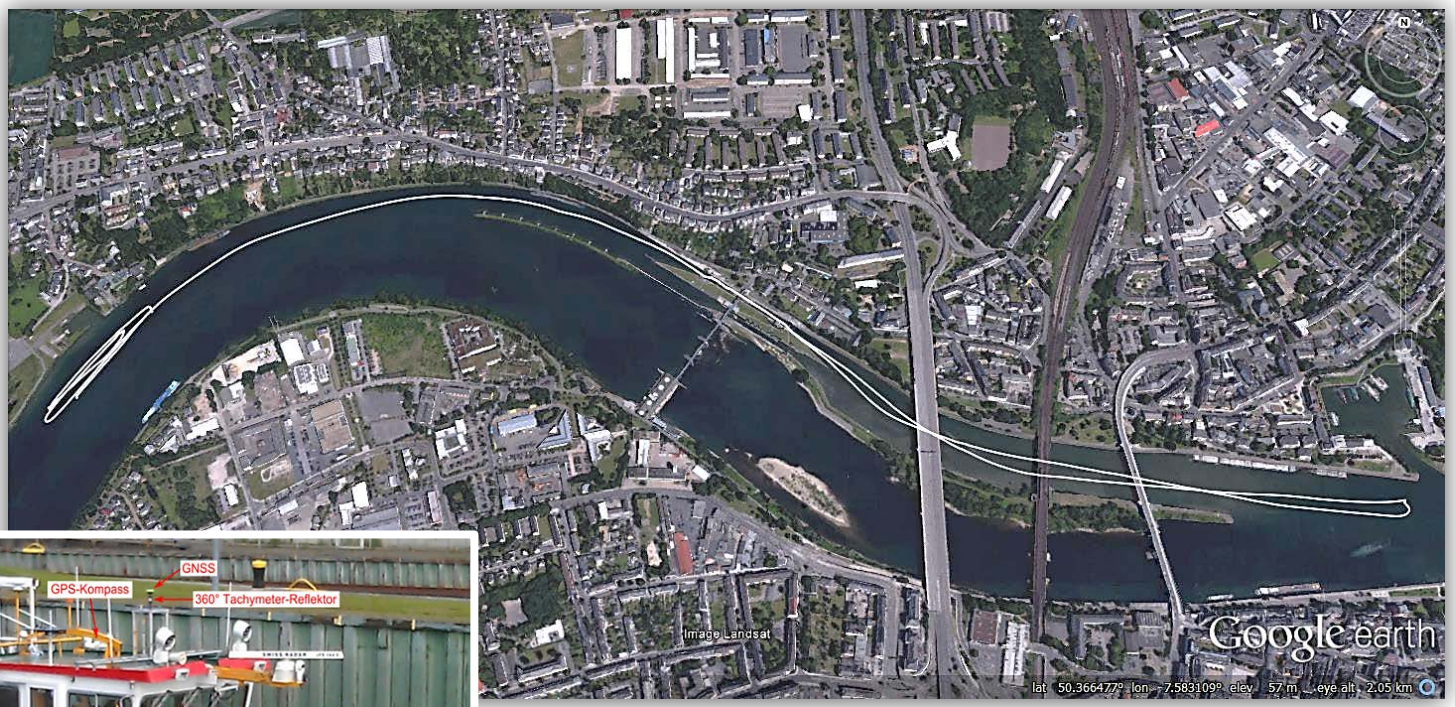


Satellite navigation (GPS, Galileo,…)

Inertial navigation (IMUs)

Others:
- **Maps**
- **Speed log**
- **etc…**

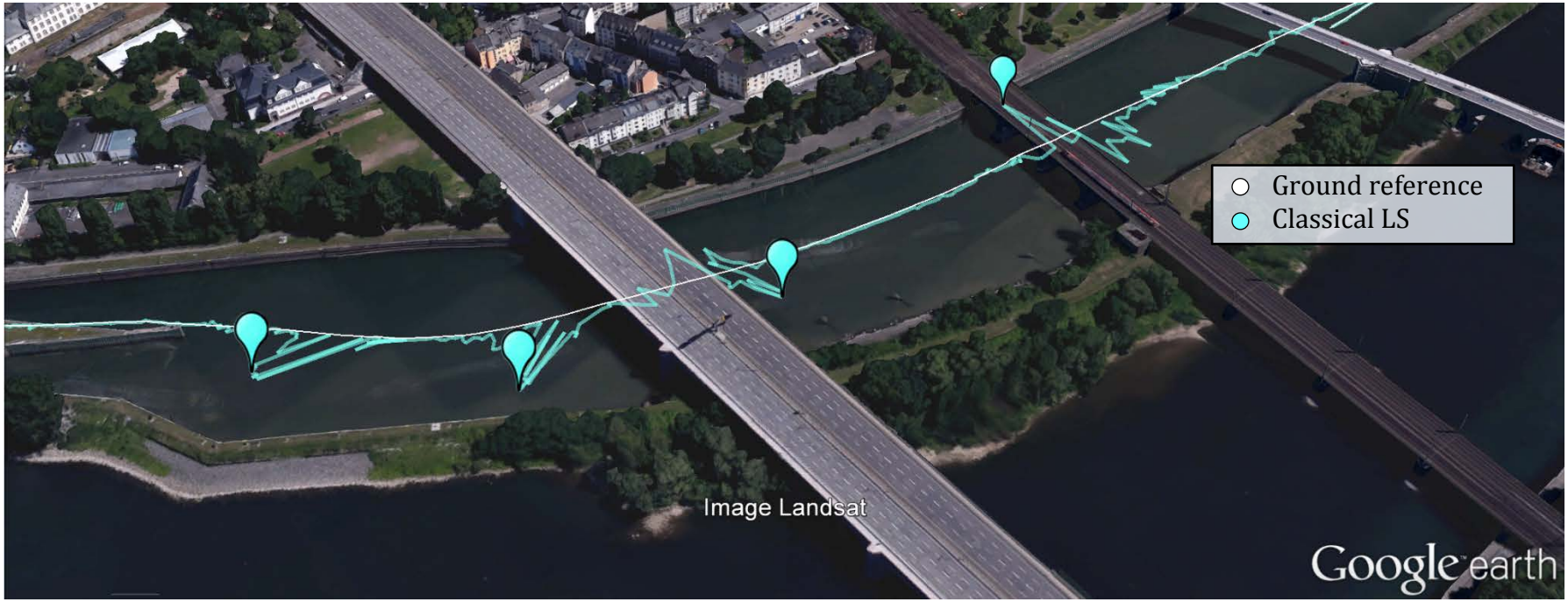
Case Study: Mitigation of Errors for a Challenging Scenario



- Test scenario in the Moselle River in Koblenz (one of the busiest waterways in Germany)
- Vessel *MS Bingen* performed 8 – shaped trajectory passing under the bridges
- The bridges block and reflect the satellite signals → multipath effects

Case Study: Performance of Standard Techniques

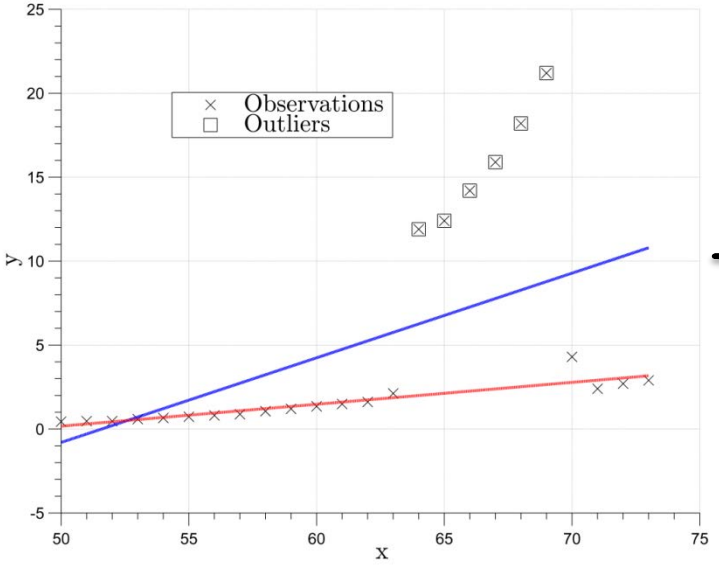
- Standard positioning techniques completely fail nearby the bridges (errors of more than 50 meters!)
- Under low visibility conditions, vessels could easily collide against another vessel or against the pillars of the bridges
- Autonomous navigation cannot be provided (accuracy requirements not fulfilled!)

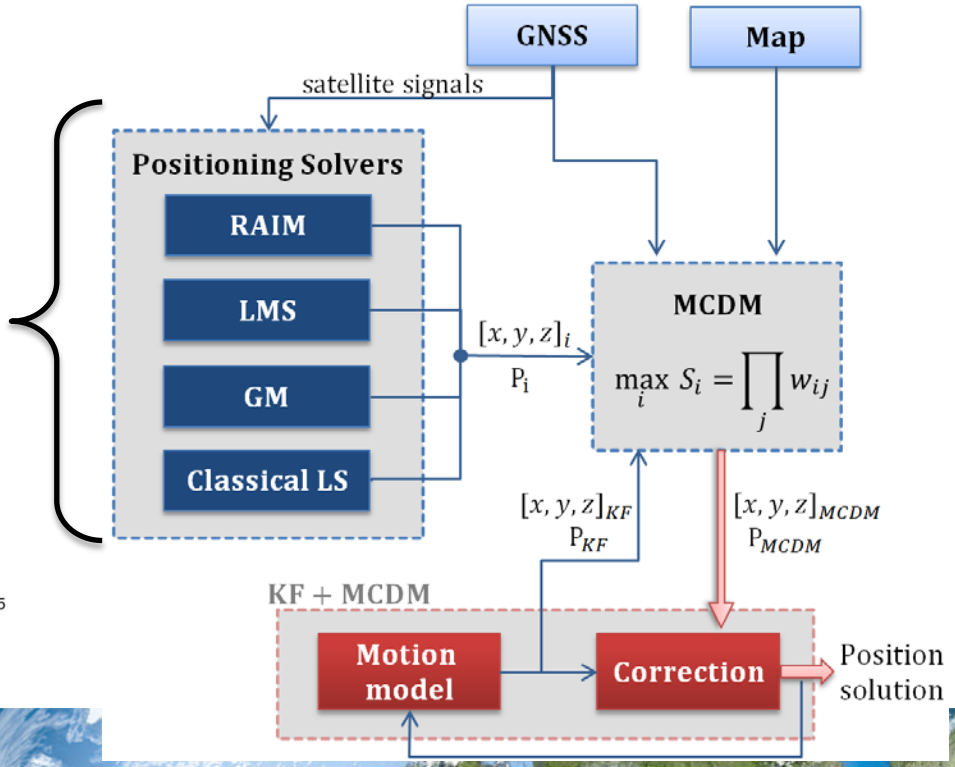


Case Study: KF – MCDM, our Solution

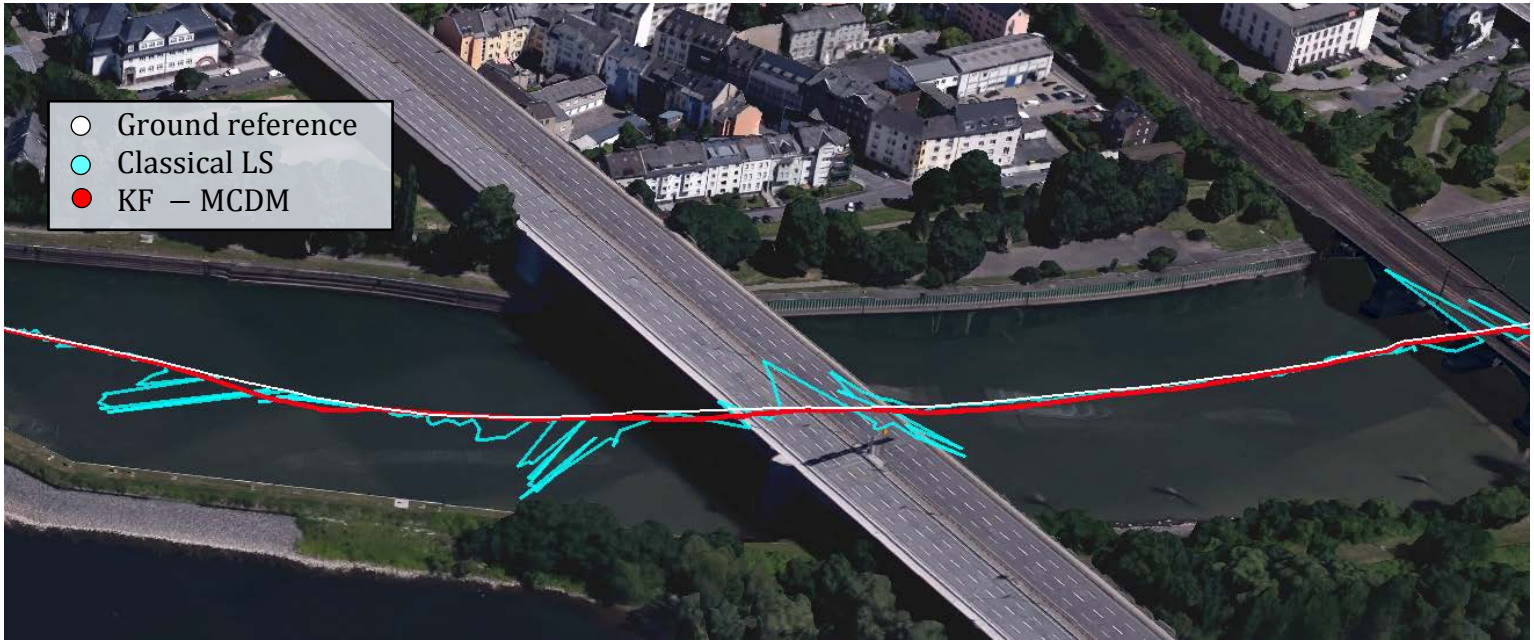
- Use of **K**alman **F**ilter (**KF**) for the sensor fusion and estimation of the position
- Different methods (**RAIM**, **GM**, **LMS**) with complementary characteristics

Context can be exploited to choose the best estimator at every moment → **M**ulti **C**riteria **D**ecision **M**aking (**MCDM**) problem





Case Study: Performance of the Proposed Technique



Method	Mean HPE [m]	RMS HPE [m]	Max HPE [m]
LS	2.9	4.5	50.7
KF-MCDM	2.5	2.9	10.4

KF – MCDM* is a filter technique designed to detect and reject „bad" satellite signals

- ✓ Max error is reduced more than 40 m compared to classical positioning!
- ✓ Fusion of GPS, IMU and map information

* Source: Medina, Daniel Arias, et al. "Context-enhanced information fusion for tracking applications." *2016 19th International Conference on Information Fusion (FUSION)*

Summary and Outlook

The maritime community still faces several challenges related to positioning and safe navigation **but…**
Sensor fusion & ***outlier*** **detection** algorithms are a big part of the solution

Nonetheless, there is still a long way to go…

- Integration of additional on-board sensors: RADAR, anemometer, etc.
- Integrity concept for multi-sensor systems:
  - Error bounds in integrated navigation system
- Extension to **MMM**: **M**ulti-antenna, **M**ulti-constellation, **M**ulti-frequency
- Fusion of phase measurements (precise positioning)


Thanks for your Attention
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